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THE PERMO-CARBONIFEROUS OF NORTHERN NEW MEXICO

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The age of the Red Beds of the Rocky Mountain region has long been in doubt. They outcrop extensively along the eastern foothills, extending across Wyoming from the Laramie Mountains to the Wind River Range, thence through eastern Utah and western Colorado, with extensive exposures in the southwestern part of that state; in various places in northern New Mexico, from the San Juan region east; southwestward in the Ft. Wingate region; and along the eastern part of the same state. On the plains are extensive outcroppings in southwestern Kansas, thence across Oklahoma into the northern and western parts of Texas. Vertebrate fossils of Triassic age have been reported from the Lander region (Williston, Branson), Como and Red Mt. (Reed and Williston) in Wyoming; from northeastern Utah (Lucas); western Colorado (Cross); northern New Mexico (Cope); Fort Wingate, New Mexico (Yale collections, Shufeldt); Pan Handle (Cope), and Claremont, Texas (Brown). The fossils, consisting chiefly of phytosaurs and labyrinthodonts, agree, for the most part, so closely with those of the Keuper of Europe that their horizon may be confidently fixed as Upper Trias. Below the horizon yielding

these remains there are rocks of about nine hundred feet in thickness in the Lander region, and perhaps more in the southern region, which have been hitherto supposed to be utterly barren of all fossils, whether vertebrate or invertebrate; and there are at least three hundred and fifty feet immediately underlying strata of certain Upper Trias age which have never, in any place, yielded fossils.

Everywhere characteristic of the uppermost beds, from Lander to New Mexico, Kansas, and Texas, are from five hundred to possibly a thousand feet, as estimated, of barren or almost barren measures, characterized by the lighter colors of the sandstones, often of aeolian origin, and more or less interspersed or capped with massive beds of gypsum, as at Lander, in Kansas, Texas, and New Mexico. The age of these upper beds throughout is assumed to be Triassic, but we know of no evidence whatever, save the color of the rocks, to differentiate the uppermost of them from the Jurassic,¹ which lie in some places quite conformably above them. At Cañon City, Colo., the Hallopus beds, lying conformably immediately above the Red Beds, have been supposed by Marsh to be either of Lower Jurassic or Upper Triassic age, and the senior author from an examination of them agrees quite with his opinion. With this possible exception there are no fresh-water deposits in North America of Lower Jurassic age, the beds lying immediately above the Red Beds, whether conformably or not, being either the marine Jurassic (Sundance), or Morrison of uppermost Jurassic or lowermost Cretaceous age.

At the base of these barren measures of Upper Trias or Jurassic age, in the Lander region, are thirty or more feet of massive sandstones, red, whitish, or variegated in color, underlain by pebbly conglomerates and clays, in which occur the remains of vertebrate fossils, if not in the sandstones themselves. Below these fossiliferous beds, in this region, are nine hundred feet of red sandstones and clays, as recently accurately determined by Branson (*in lit.*) lying conformably, both with the overlying Upper Trias sandstones and the underlying beds of Pennsylvanian age (Embar beds, Branson), in which no fossils of any kind have ever been detected, though

¹ These measures were referred by Cope to the Jurassic many years ago (G. M. Wheeler, *Annual Report*, 1875, pp. 78 ff.).

we are of the opinion that careful, persistent search in the lower two or three hundred feet will be rewarded with vertebrate remains. In Kansas the Red Beds have been estimated to be one thousand feet in thickness and said to be utterly unfossiliferous, by Cragin

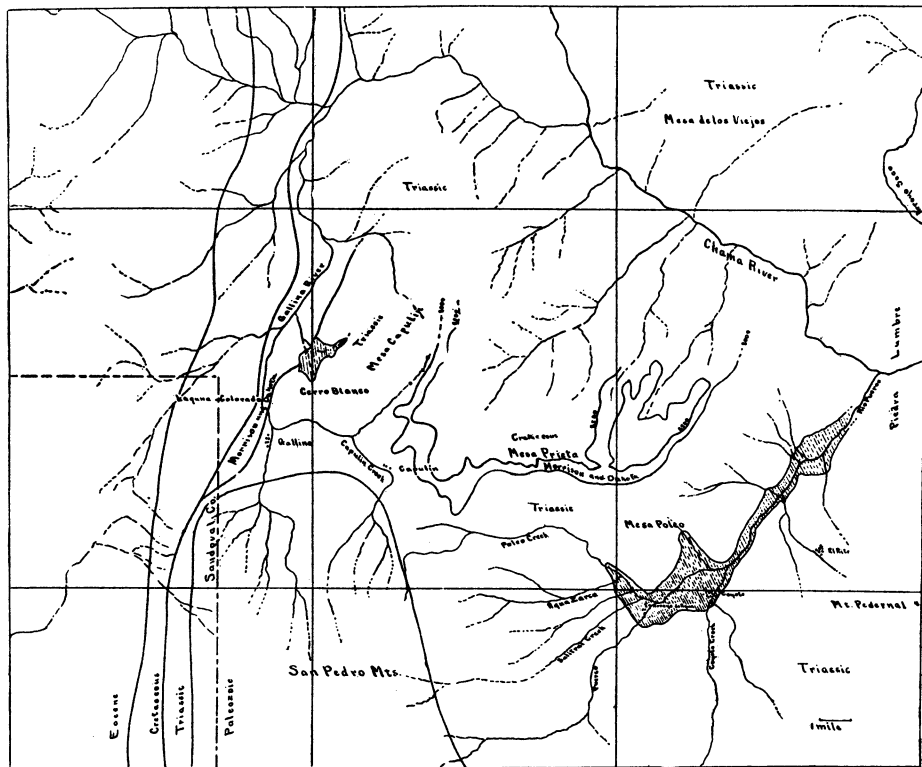


FIG. 1.—Map of Mesa Prieta and adjoining country. The fossiliferous Permo-Carboniferous is shown in the areas indicated by broken lines. Comparison with the Jemez topographic sheet will make details evident.

and Hay. From just south of the Kansas line Professor Gould some years ago obtained very typical remains of the amphibian *Eryops* (*E. Willistoni* Moodie), a characteristic "Permian" fossil, and it is very probable that intelligent search will show, somewhere between this horizon and the barren beds of southern Kansas, the

characteristic massive sandstones and phytosaur remains, more probably so since such fossils have been actually found not far to the west.

Cross has reported unconformity of the Red Beds in western Colorado, but it has been our experience, wherever we have examined them, that they lie conformably throughout, so far as stratigraphical evidence indicates. In Kansas, Oklahoma, Texas, and eastern New Mexico they seem to be thicker, perhaps reaching two thousand feet in their totality. In northern New Mexico our observations the present year give a thickness of not over sixteen hundred feet, while in the Lander region their total thickness is fourteen hundred and forty feet, as recently accurately determined by Professor Branson.

More than thirty years ago, the late David A. Baldwin collected from the Red Beds of northern New Mexico, which he considered of Triassic age throughout, considerable quantities of vertebrate fossils, the most of which are now preserved in the museum of Yale University, and the remainder in the American Museum of New York City. At the time of their collection two or three very brief descriptive papers, referring them to the Permian, were published by the late Professors Marsh and Cope, but without giving any further information as to the locality of their origin than simply New Mexico. Within the past few years the present writers have published further notes and descriptions of the remains in these collections, with more definite information of their occurrence. With more precise information kindly given by Professor Schuchert an expedition was planned to explore the region the past summer. This expedition, composed of Mr. Paul Miller of the University of Chicago and the present writers, entered the field the early part of July from Espanola, near the mouth of the Chama River, with Abiquiu as the chief base of supplies. Dr. v. Huene was a member of the party for three weeks. Abiquiu, one of the oldest settlements in the United States, is located twenty-seven miles northwest of Espanola on the Chama. It is our pleasure to acknowledge with gratitude the kind favors shown us here by Mr. Henry Grant.

From Abiquiu our entrance into the Red Beds was made in the

famous cañon known as El Cobre, so named because of the indications (indications only) of copper long known there. From thence the expedition followed the valley of the Puerco to the embouchure of its chief tributary, the Poleo (Arroyo de Agua). Later a brief trip was made to the valley of the Gallina, and as far west as the Wasatch deposits in Sandoval County.

From Espanola to Abiquiu the road follows the sandy valley of the Chama, bordered by Tertiary deposits, coarse white sandstones, often eroded into typical badland forms, and leading up to lava-capped table-lands. Three or four miles west of Abiquiu the Tertiary sandstones lie immediately upon heavy beds of red clays and red sandstones of Triassic age. In the immediate stream bed

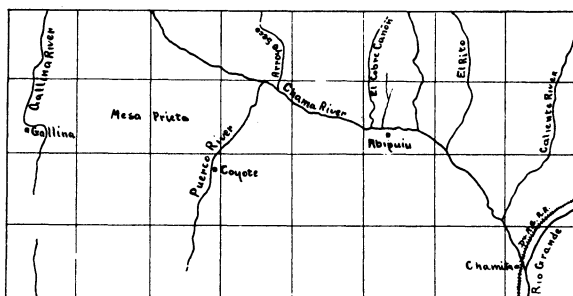


FIG. 2.—Map of region about Abiquiu showing location of El Cobre Cañon

of the Cobre creek we observed conglomerates twenty or more feet in thickness, composed of quartzite boulders reaching six or eight inches in diameter, and almost devoid of binding matrix. Farther northwest and toward the entrance into the Cobre basin there are fifty or more feet of red and variegated clays, which in turn are underlain by from fifty to seventy-five feet of more massive sandstones, with a more or less persistent conglomerate pebbly layer beneath them, yielding phytosaur remains. It is through these sandstones that the outlet of the basin occurs in a narrow but not deep gorge.

El Cobre Cañon or basin is formed by the erosion of an unsymmetrical dome-shaped anticline more or less faulted on the northeastern and southeastern sides, the brim formed everywhere by the massive sandstones of basal Upper Triassic age, the strata sloping

in all directions, but chiefly east and west. The basin thus formed is about two and a half miles in its greatest extent, in a north-and-south direction. Its very steep walls, for the most part about seven hundred feet in altitude, attain their greatest height in the north-west part, where the altitude may exceed eight hundred feet, and where the Permian exposures are the greatest.

The erosion of the floor of this basin, acting on the beds of alternating sandstones and clays, has formed a series of steps or low cliffs, which for the most part dip at a small angle toward the west. Toward the sides and upper end of the cañon these ridges become more prominent, frequently forming high bluffs and cliffs. The lowermost beds in the cañon are deep chocolate-colored sandstones and fine conglomerates; the latter weather into low, rounded hills, frequently streaked with greenish layers. Bone fragments were found in these layers in various places in the basin. Above these darker colored sandstones are more massive sandstones, weathering more or less whitish, which ascend at the north end of the cañon to perhaps three hundred and fifty feet above the stream bed. All vertebrate fossils that we found, of Permian age, were below these sandstones, which form a fairly definite horizon about the basin, and which may be taken as the lower limits of the Trias.

It has been questioned by us elsewhere whether the vertebrate fossils found in Texas, Oklahoma, southern Kansas, Illinois, and Pennsylvania are really of Permian age. At the south side of the cañon, the junior author found a perfect cast of a *Spirifer*, identified by Professor Schuchert as *S. rockymontanus* Marcou, a form occurring in Colorado in the Pennsylvanian. Though the specimen was found free, so that its exact horizon could not be determined, its excellent preservation proves conclusively that it had not been carried far from its original bed, and inasmuch as vertebrate fossils are found in the deepest strata of the cañon it seems quite certain that the specimen came from an intercalated bed among those yielding so-called Permian vertebrates. No other explanation seems possible. It is the conviction of both the present authors that the lowermost at least of the strata yielding vertebrate fossils are of Pennsylvanian age, and this conviction is strengthened by the known position of the vertebrate horizons in Texas, Kansas,

Illinois, and Pennsylvania, that of the last-named region definitely known to be Pennsylvanian.

Below is given a section (Section I) of the west wall of the Cobre Cañon as far down as the horizons yielding fossils of paleozoic age. It must be especially remembered, however, that this, as

SECTION I

EL COBRE

Yellow sandstone and conglomerates	75	Upper Trias	
Purplish and gray clays	40	"	
Purplish sandstones	20	Lower Trias?	Barren
Purplish clays and nodular sandstone	25	"	"
Red sandstone	5	"	"
Bright red clay	35	"	"
Purple clay	12	"	"
Bright red sandstones	22	"	"
Coarse purplish sandstones	12	"	"
Bright red clay with greenish nodules and purplish bands	100	"	"
Coarse, hard purplish sandstone	8	"	"
Bright red clay and sandstone	65	"	"
Hard red and purplish sandstone	6	"	"
Bright red sandy clay, with purplish streaks . . .	90	"	"
Purplish and dark brown clay	22	"	"
Red clay and hard red sandstone	30	"	"
Hard purplish sandstones	35	"	"
Red clay	7	?	
Purple sandstones	3	?	
Red clay	22	?	
Permo-Carboniferous: red, brown sandstones and clays, fossiliferous			

also the other section given in this paper, will not apply in detail to any other place, since it has been our experience in the Red Beds that detailed sections made in any given place cannot be depended upon perhaps a quarter of a mile away. The top of this section, as already stated, yields vertebrate fossils of Upper Triassic age, and some of the Triassic vertebrates described by Cope from New Mexico came from the El Cobre Cañon.

A survey of the surrounding country from the summit here, as also from the Piedra Lumbre, shows everywhere these basal Upper Trias rocks as the lower or lowermost exposures.

From the El Cobre Cañon the expedition turned westward on the Chama to the mouth of Cañones creek, and then southwest across the Piedra Lumbre Mesa to El Rito, or "branch" of the Puerco. The top of this mesa is of Upper Triassic age, and, near the base of Mt. Pedernal, which rises several hundred feet above the mesa, appears for the first time the heavy layer of gypsum marking the upper limits of the Red Beds, or so-called Trias. From the top of this mesa a good view of the adjacent country is afforded. To the north is the Mesa de los Viejos, with the Chama apparently occupying a fault line between, and the Arroya Seco in a valley formed by the basal Upper Trias rocks sloping from the brim of the Cobre Cañon on the east and the superincumbent Triassic rocks on the west. To the west lie the Mesa Prieta and the smaller Capulin Mesa, separated by the Puerco, Chama, and Capulin streams, whose courses seem to have been influenced strongly by the faulting and dipping of the Trias.

The Puerco to the mouth of the Poleo has cut down into Permian strata, which attain their greatest exposure on the Poleo about one mile from its mouth. Our first camp was made on the Poleo (Arroya de Agua), about one mile above its confluence with the Puerco.¹ Near the junction of the two creeks there is a steep walled cliff of Permian rocks about a hundred feet in height, with a more or less flat table-land above it a mile or so in extent separating it from the Trias above. Farther west, where the Permian rocks find their greatest exposure, and where the Baldwin quarry is, from which so many of the fossils in the Yale collection came, the very steep bluffs, in many places so steep as to be unclimbable, are about seven hundred feet in height, composed of alternating red sandstones and clays, with white and purple sandstones, clays, and conglomerates at the upper part, corresponding quite to the massive sandstones forming the brim of the Cobre Cañon, and which form the top of the Mesa Poleo, dipping northward to the foot of the Mesa Prieta. Phytosaur bones were found at the base of this white sandstone and in the pebbly conglomerates immediately underlying them. Permian fossils were found only in the lower-

¹ This Puerco creek is not the one which gave origin to the name of the Puerco formation, a stream by the same name farther to the southwest.

most three hundred feet of these exposures, the intervening three hundred feet of more or less vertical red clays and sandstones here, as everywhere else in the Rocky Mountain region, being quite barren. These rocks lie here, as elsewhere, apparently quite conformable with the superincumbent and subjacent beds, and doubtless represent the Lower Trias and perhaps more or less of the Upper Permian. The section of the bluff herewith given was made opposite our first camp on the Poleo, about one mile from the mouth of the creek; as is the case with the section at El Cobre, it can be depended upon only for a short distance on either side; the strata often change abruptly from sandstones to clays and vice versa.

On the north side of the immediate valley of the Poleo the strata dip northward to the walls of the Mesa Prieta; immediately south of the creek they dip abruptly southward. About two miles above the mouth of the creek the beds bend down sharply and disappear beneath the alluvial deposits of the creek bed, doubtless indicating the line of a fault. Beyond this point the walls of the Mesa Prieta, formed exclusively of Upper Triassic and superincumbent beds, descend to the immediate valley of the Poleo and Capulin creeks.

The Mesa Prieta rises about fifteen hundred feet above the beds of the Poleo and Capulin. Near the middle of the bluffs, at about the 8,000-foot line, there is a heavy bed of gypsum, which is taken to be the upper limits of the Trias, though, as we have said, in the entire absence of all fossil remains through four hundred feet of these beds at least, everywhere, their age is assumed simply from their color—evidence, to say the least, that is exceedingly dubious, the more so from the fact that there is no petrological distinction between the Trias and Permian. Above this gypsum layer are the brownish and purplish shales of the Jurassic¹ and the lighter colored sandstones of the Cretaceous all lying quite conformably with the Red Beds below.

About a mile and a half beyond the little settlement called

¹ The beds immediately overlying the gypsum have been called Dakota by Darton (*Bull. U.S.G.S. No. 435*) and Shaler (*Bull. U.S.G.S. No. 315*, p. 262), but without any evidence therefor. We searched in these shales for fossils, but without success. Elsewhere the beds overlying the Trias are either the marine Sundance (Wyoming), the Hallopus beds (Cañon City, Colo.), Morrison (Southern Wyoming), or Lower Cretaceous (Kansas).

SECTION II

POLEO CREEK

Gray sandstones, mostly even grained with pebbly conglomerates and shales below.			
Phytosaurs	30	Upper Trias	
Softer gray sandstones, weathering into sand . . .	30	?	
Sandy clay, with beds of thin black shale; plant remains, fossil wood	40	Upper Trias?	
Sandy clay, black and green	12	Lower Trias?	Barren
Purplish sandy clay	6	"	"
Coarse yellow sandstone	33	"	"
Loose gray sand	6	"	"
Green and purplish sandstones	3	"	"
Gray and purplish sandstones	12	"	"
Hard clay, variegated and jointed (cliffs)	3	"	"
Purplish sandstones and red clay	30	"	"
Loose white sand with beds of red clay	40	"	"
First red nodular layer	6	"	"
Soft fine-grained, light red sandstones, cross-bedded, forming tops of pyramids and cliffs . .	6	"	"
Soft fine-grained, light red sandstones, cross-bedded with lighter bands of pebbles	3	"	"
Second red nodular layer, with clay	3	"	"
Red clay	2	"	"
Coarse cross-bedded sandstones	6	"	"
Third red nodular layer	6	"	"
Red cross-bedded sandstones	12	"	"
Dark red and green clay	3	"	"
Coarse red and green sandstones	17	"	"
Hard red sandstones, cliffs	3	"	"
Red sandstone and clay with thin band of harder sandstone	18	"	"
Hard, red coarse sandstone	3	"	"
Red clay	35	"	"
Red sandstone, bluffs	23	Base (?) of Trias	
Red sandstone with thin seams of clay, reptile bones	18	Top (?) of Permian	
Red clay with thin nodular layers	55		
Dark red, coarse sandstones (cliffs)	6	Permian, fossiliferous	
Red sandy clay	35	"	
Dark red, coarse sandstone, jointed	18	"	
Red clay, even texture, vertical rain erosion . . .	50	"	
Dark red clay	8	"	
Red shaly clay	17	"	
Heavy gray sandstones	25	"	
Red sandstones and clays	?	"	

Capulin a stream flows into Capulin creek from the north along the line of a fault which divides the Mesa Prieta from the Capulin Mesa. The strata of the Mesa Prieta at this point dip slightly northwest, but those of the Capulin Mesa dip east and northeast. The west face of the Capulin Mesa rises a thousand feet or thereabout above the valley of the Gallina River. Just north of the Cerro Blanco there is a high red wall similar to that north of the Poleo creek, the uppermost rocks bearing phytosaur remains. It is confidently believed that the lowermost exposures here are of Permian age, but no fossils were found.

There is a sharp break between the Capulin Mesa and the Cerro Blanco. The rocks of the latter dip sharply to the west, and are overlain by the Jurassic shales and the Cretaceous sandstones and shales. At the foot of these Upper Triassic rocks, north of Cerro Blanco, and opposite the face of the Capulin Mesa bluff before referred to were found various small fresh-water invertebrates, and bone fragments referred provisionally to the genus *Coelophys* Cope. The horizon of these remains can hardly be less than one hundred feet above the basal Upper Trias sandstones, and, in all probability, the original types came from the immediate locality whence the fragments were found by the junior author. The Cerro Blanco takes its name from the massive beds of white gypsum which cap it, descending steeply below the creek bed to the south and dipping to the west. From the top of the Cerro Blanco one can look miles to the north and west, and the view therefrom is a revelation to the geologist. To the east lie the mesas of more or less horizontal rocks of predominantly Upper Triassic age; to the west the strata are deeply tilted and eroded into valleys; a few miles farther west the beds of the Wasatch badlands lie horizontally upon the uptilted edges of the Mesozoic strata.

Upon the whole, the general features of the Red Beds in northern New Mexico, as in many places elsewhere, may be summarized as follows:

The Upper Trias rocks, about six hundred feet in thickness, perhaps more, are predominantly softer and lighter colored, often orange colored, yellowish and whitish, and more aeolian in character, with the upper or uppermost beds more or less gypsiferous.

These beds, as in the Lander region, have basal sandstones, reddish or white, with conglomerate and clay layers below them yielding phytosaur and labyrinthodont bones (both types were found at El Rito), corresponding well with like vertebrates from the Keuper of Europe. Below these beds there are not less than three hundred and fifty feet, in the Lander and Kansas regions perhaps nine hundred feet, of more uniform red sandstones and clay layers, usually weathering into more vertical bluffs, that are utterly barren of all fossils and supposed to be of Lower Triassic and Upper Permian age. Below these and conformable with them, in New Mexico and probably elsewhere, are not less than three hundred feet, probably more, of prevailing coarser and darker colored, often brownish sandstones, and dark-colored clay beds, yielding vertebrate remains hitherto considered to be of Permian age, but which in all probability are in part at least of upper Pennsylvanian age.